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| Math 362 |
| Fourier Analysis of Cats |
| Dr. Gustafson |

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**Aim of Analysis**

For this year’s final project, I have chosen to use Fourier techniques on different sounds from cats. The aim of analyzing the different sounds of cats is to see what differences lie in the sound waves of cats according to their mood. This essentially means that I believe there is a distinct difference in what a sound wave of a cat will look like according to its mood or what the cat is trying to communicate. The main sound waves that I intend to look at are purrs, meows, and aggressive meows from cats. This will give a wide variety of sound waves to look at and to use for the different moods for the cats. I have a cat that I myself intend to get some recordings from, but the rest will be found online for analysis (Gay) and (Wavsource). The textbook, “Elementary Fourier Analysis” has the commands and techniques used to analyze the sound waves presented in this project (Gustafson). Images are referred to without the, “#” in “Figure.#”.

**Techniques Used**

Most of the techniques used to analyze the cat sound waves are found in the textbook, “Elementary Fourier Analysis” (Gustafson). From this textbook we used several sound wave MATLAB commands including,

* SoundWaveTimeFreq(x,sr,TZL,TZR,FZL,FZR)
* audioread(‘audio.wav’)
* SpectrogramPlot(z,sr,ymax)
* BandPass(x,sr,domfreq,BandL,BandR,PlotL,PlotR)
* BandStop(x,sr,domfreq,BandL,BandR,PlotL,PlotR)

**Analysis and Results**

The following tables contain MATLAB commands and their outputs, plots will be input into the tables when they are applicable for the commands used. All soundwaves have two sections with the time and frequency domain plots being one section where the other is the actual signal processing done on the soundwave.

**Part One: Time Domain, Frequency Domain, and Spectrograms**

**Part 1A. Cat Purring**

This soundwave was recorded in person.

|  |  |
| --- | --- |
| Input Commands | Output |
| >> [x,sr]=audioread('bellapurring.wav');  >> SoundWaveTimeFreq(x,sr,4.23,4.33,1,500)  >> sr  sr =  44100  >> N=length(x)  N =  580607  >> T=N/sr  T =  13.1657 | Figure 1.  Figure 2. |

From figure 1 and 2, the partial time domain plot shows a pattern amongst the soundwave that is periodic (or close to) in the short ten second time interval observed. For this specific soundwave, the highest frequency can be seen around 600 Hz from the frequency domain plot with the most common frequencies coming from the 0 to 50 Hz range. This implies that a cat’s purr is a low frequency somewhat periodic soundwave. More verification comes to this from the following spectrogram plot.

|  |  |
| --- | --- |
| Input Commands | Output |
| >> [z,sr]=audioread('bellapurring.wav');  >> SpectrogramPlot(z,sr,600) | Figure 3.1 |

From figure 3, we can see in this 13 second time interval that the most dominant frequencies found in the cat’s purr are primarily low frequencies. From these low frequencies, we see that the dB/Hz distribution in the diagram is primarily low (around 50 dB/Hz) and this is indicative of a soft sound. Anyone who has a heard a cat purr before knows that it isn’t a very sharp sound and it also isn’t very loud. The partial time domain plot from figure 1 shows that the soundwave of a cat purring is somewhat periodic (neglecting the sharp small differences amongst periods), this can also be thought of as a softer sound. Something like a weed-eater or a lawnmower changing pitch when used could be thought of as a sharp sound. The results displayed in figure 3 show that the sound is also somewhat quiet, and this jells with the idea that the cat’s purr is a soft sound from the periodic nature of it. The following two figures are all the plots of this soundwave. This soundwave was hand recorded with no online resources used.

|  |
| --- |
| Plots of Cat Purring |
| Figure 4.  Figure 3.2 |

The following commands and plots come from a different soundwave, instead a cat purring, the following soundwave is from a cat that is meowing in a neutral tone.

**Part 1B. Cat Meowing**

This soundwave was obtained from an online resource (Gay).

|  |  |
| --- | --- |
| Input Commands | Output |
| >> [x,sr]=audioread('catmeow.wav');  >> SoundWaveTimeFreq(x,sr,0.2,0.21,500,700)  >> sr  sr =  11025  >> N=length(x)  N =  8928  >> T=N/sr  T =  0.8098 | Figure 5.  Figure 6. |

From figure 5 and figure 6, the soundwave of a cat meowing in a neutral tone can be seen to be periodic as well. This is much like the findings from the soundwave of a cat purring. Figures 5 and 6 show that in the tiny 0.1 second time interval that a pattern comes from the cat meowing’s soundwave, therefore it can be said that it is somewhat periodic. The same shape seems to be repeated over and over in just this tiny interval. The following table depicts the commands used and to create the following spectrogram plot.

|  |  |
| --- | --- |
| Input Commands | Output |
| >> [z,sr]=audioread('catmeow.wav');  >> SpectrogramPlot(z,sr,1700) | Figure 7.1 |

From figure 7, there are two distinct yellow stripes across the spectrogram plot of the cat meowing. This 0.8 second time interval has a max frequency peaking at 1650 Hz and another dominant frequency that is around 1100 Hz. When playing back the soundwave this sound is higher pitch and that is seen in the spectrogram plot of figure 7. It although is not painfully evident that there are two distinct dominant frequencies of this soundwave. The two dominant frequencies can be observed on the spectrogram plot of figure 7 and it should be noted that these frequencies reside in similar frequency windows of about 200 Hz each. These dominant frequencies can be observed from a different perspective back in figure 6. It should be noted that the partial plots of the frequency and time portray similar characteristics amongst other intervals of the same length. The following table has all the plots from this one soundwave.

|  |
| --- |
| Plots of Cat Meowing |
| Figure 8.  Figure 7.2 |

The third soundwave that is analyzed is the soundwave of an angry cat. The focus of this specific soundwave is to observe the randomness from the change in tone amongst a cat that is very upset. This soundwave should look different from the other two since this soundwave is more hectic than the previous soundwaves.

**Part 1C. Mad Cat**

This soundwave was found off of an online resource (Wavsource).

|  |  |
| --- | --- |
| Input Commands | Output |
| >> [x,sr]=audioread('catscreech.wav');  >> SoundWaveTimeFreq(x,sr,0.4,0.41,1700,1800)  >> sr  sr =  11025  >> N=length(x)  N =  16576  >> T=N/sr  T =  1.5035 | Figure 9.  Figure 10. |

From the figures 9 and 10, it is evident that this sound wave is somewhat periodic at a small scale. From a larger time interval, the soundwave looks like a jumbled mess. When the soundwave is zoomed in on it should be noted that the same rough shape repeats itself over and over in just the small interval. From the larger time interval, the soundwave looks like one shape. Therefore, the interval from 0.4 seconds to 0.41 seconds was chosen, to highlight the periodic shape at a small level. From the frequency domain plot from figure 10, it is observed that the highest frequency from this soundwave is 1900 Hz. From figure 10 it can be seen that the high frequency jumps back down to low in a short time interval, lending a big part in why this sound is high pitched. This high frequency jells with what a listener would hear if this cat made this sound in front of them. This high frequency spread can be seen in the following spectrogram plot.

|  |  |
| --- | --- |
| Input Commands | Output |
| >> [z,sr]=audioread('catscreech.wav');  >> SpectrogramPlot(z,sr,1850) | Figure 11.1 |

The spectrogram plot in figure 11 shows that this soundwave has a high dB/Hz ratio which is indicative of a soundwave that is high pitched. This also jells with the intuition of the listener because the sound is loud and can be seen with the high frequency spread in the frequency domain plot of figure 10. The mad cat soundwave and its plots can be seen in the following table.

|  |
| --- |
| Plots of Mad Cat |
| Figure 12.  Figure 11.2 |

This soundwave has high frequency terms in it that contribute to a high-pitched sound. Anyone who has been around cats knows the sound that comes from cats when they are fighting or are very upset tend to be louder to the human ear. This is what is meant by the high-pitched sound that is observed in the mad cat soundwave. These features of the soundwave can be observed in the plots of figure 12 and figure 11.

**Part Two: Signal Processing**

This section is concentrated on the BandPassing and BandStopping for the soundwaves in this project. As mentioned before, the main signal processing tools that will be used in this section are BandPass and BandStop but other tools like RawSoundThresh will be used. Plots and commands used in MATLAB will be put into tables below.

**Part 2A. Cat Purring**

This soundwave was recorded in person.

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('bellapurring.wav');  >> BandPass(x,sr,100,1,200,1,600) |

|  |
| --- |
| Output |
| Figure 13.1  Figure 14.1 |

Looking at figure 13 and figure 14, the BandPass technique used smooths out the soundwave which can be seen in figure 13 but observed more carefully in figure 14. Oddly enough, when this BandPassed soundwave is played back it is so quiet it is almost inaudible. The sound is muffled extremely when it is put through this range for a BandPass. The next table depicts the commands used to BandPass this same soundwave but at a different frequency range.

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('bellapurring.wav');  >> BandPass(x,sr,50,300,600,1,600) |

|  |
| --- |
| Output |
| Figure 15.1  Figure 16.1 |

Figure 15 and 16 depict the output of the BandPassing of this soundwave at a different frequency range. When this BandPassed soundwave is played back, it sounds like the original sound is being played back but it is muffled. The biggest difference between the original soundwave and the BandPassed soundwave this time is that the BandPassed soundwave doesn’t keep the lower frequencies from 1 Hz to 300 Hz so it will sound different. When the original is played back, it is evident that a cat is purring and that is what the soundwave is of, when the BandPassed is played back the listener can still tell that it is a cat purring but it is a lot harder to come to that conclusion. Figure 16 can demonstrate the huge contrast that is from the original to the BandPassed. Figure 15 shows what the original looked like in comparison with the BandPassed side by side. The next table depicts the BandStopping of the same soundwave.

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('bellapurring.wav');  >> BandStop(x,sr,100,1,200,1,600) |

|  |
| --- |
| Output |
| Figure 17.1  Figure 18.1 |

When the BandStop is played back, it sounds very similar to the original sound wave. The frequency domain graph from the BandStop (top right of figure 17) has the frequencies from 0 Hz to 200 Hz BandStopped. Figure 18 shows a much more smoothed out soundwave than the original. The BandStopped soundwave sounds so much like the original it is hard to distinguish the two from one another. From this it should be noted that the BandStop has no purpose on this soundwave, other than wanting to eliminate some of the data in the soundwave. The following tables show the commands used to demonstrate the BandStopping of the same soundwave but at different frequency ranges.

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('bellapurring.wav');  >> BandStop(x,sr,50,300,600,1,600) |

|  |
| --- |
| Output |
| Figure 19.1  Figure 20.1 |

Figures 19 and 20 show the BandStopping of the Bella purring soundwave at a different frequency spectrum. This time, when the BandStopping is used on this soundwave the BandPassed soundwave is not as smooth like it was at the lower frequency range. Figure 20 shows how this soundwave looks after it is BandStopped. When the BandStopped soundwave of a cat purring is played back, the soundwave sounds almost identical to the original with no signal processing done on it. From the previous BandStop on the same soundwave, it was also observed that the BandStop had no effect in how it made the soundwave sound. From these two BandStops it should be noted that the BandStop process has no purpose on this soundwave. The following table is all the outputs from the signal processing on the Bella purring soundwave.

|  |  |
| --- | --- |
| Figure 13.2 | Figure 14.2 |
| Figure 15.2 | Figure 16.2 |
| Figure 17.2 | Figure 18.2 |
| Figure 19.2 | Figure 20.2 |

**Part 2B. Cat Mewoing**

This soundwave was found from an online resource (Gay). The goal of analysis with this soundwave is to see if BandPassing and BandStopping will have any effect on a cat meowing in a neutral tone and what should be deducted from those results.

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('catmeow.wav');  >> BandPass(x,sr,1100,1200,1300,1000,1400) |

|  |
| --- |
| Output |
| Figure 21.1  Figure 22.1 |

The figures from the BandPass of the cat meow show that the BandPass attempts to smooth out the soundwave and it does so in comparison to the original soundwave. The original soundwave can be seen in the bottom left of figure 21 and the BandPassed soundwave can be seen in figure 22. When the BandPassed soundwave is played back, from the frequency intervals defined in the commands above the soundwave sounds like a sharp brief pulse. This soundwave sounds like so when it is BandPassed in this domain because it is only focusing on one high frequency section of the soundwave. When the sound is played back all that can be heard is the high frequency sound, which sounds like it is high pitched. The next table shows the commands used on the same soundwave but at a different frequency range.

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('catmeow.wav');  >> BandPass(x,sr,540,1,1000,1,1000) |

|  |
| --- |
| Output |
| Figure 23.1  Figure 24.1 |

From figures 23 and 24, it should be noted that the BandPassed soundwave is in the lower frequencies this time compared to the previous BandStop of the cat meow soundwave. When the original soundwave is plotted against the BandPassed (which can be seen in figure 23) the BandStop does a good job of smoothing out the rough parts of the original soundwave. A bigger representation of the BandPassed soundwave can be seen in figure 24. When the BandPassed soundwave is played back, it sounds very similar to the original with the only difference being that the higher frequency terms don’t survive and can’t be heard when the soundwave is played back. The soundwave still sounds like it is from a cat meowing but without the high-pitched parts of the original soundwave.

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('catmeow.wav');  >> BandStop(x,sr,1100,1600,1800,1,1900) |

|  |
| --- |
| Output |
| Figure 25.1  Figure 26.1 |

When the BandStop commands are used on the cat meowing soundwave, it should be noted that there aren’t that many differences in between the original and the BandStopped. This is probably since the soundwave can still sound the same with only one of the dominant frequency spreads that can be seen in figure 25. The original and the BandStopped soundwave look very similar to one another and this can be seen in figure 25 with the BandStopped in figure 26. For the BandStopped soundwave of the cat meowing, the frequencies from 1600 Hz to 1800 Hz were BandStopped to see how it would influence the overall soundwave. What can be concluded from this is that a cat’s meow is consisted of dominant frequencies that reside in different spreads throughout. There isn’t necessarily one dominant frequency when a cat’s meow is being looked at using Fourier techniques. The following table has the commands used to BandStop the cat meowing soundwave to where only one dominant frequency spectrum remains.

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('catmeow.wav');  >> BandStop(x,sr,600,1000,1900,1,1900) |

|  |
| --- |
| Output |
| Figure 27.1  Figure 28.1 |

The figures 27 and 28 show that the BandStopped soundwave in this example is slightly different from the original soundwave. The difference in between the original and the BandStopped can be seen in figure 27. This BandStopped soundwave when it is played back sounds very similar to the original with the only difference being that this specific BandStop is a little softer in tone and pitch than the previous BandStop that can be seen in figure 28. These plots then let anyone see that this soundwave should sound very similar no matter what dominant frequency spread that is BandStopped BandStop. The following table has all the plots generated from the cat meowing signal processing.

|  |  |
| --- | --- |
| Figure 21.2 | Figure 22.2 |
| Figure 23.2 | Figure 24.2 |
| Figure 25.2 | Figure 26.2 |
| Figure 27.2 | Figure 28.2 |

**Part 2C. Mad Cat**

This third soundwave that is going to be analyzed with the BandPass and BandStop techniques is the mad cat soundwave. This soundwave sounds very different from the two previous soundwaves analyzed so this soundwave should have different conclusions in that there are more vital components to making this soundwave sound the way that it does. The following soundwave was found from an online resource (Wavsource).

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('catscreech.wav');  >> BandPass(x,sr,1700,1,1200,1,1800) |

|  |
| --- |
| Output |
| Figure 29.1  Figure 30.1 |

From the BandPass of the mad cat soundwave the higher frequencies were taken out (BandPassed) and the lower frequencies remained. This can be seen in figure 29 in the top right. The purpose for BandPassing this specific frequency spectrum is to see how similar the BandPassed soundwave will sound from the original. When the BandPassed soundwave is played back it sounds similar but without the high frequency and high-pitched parts that can be heard in the original soundwave. From figure 30, it should be noted that the BandPassing does a good job in smoothing out the soundwave from the original but it does not retain the higher frequencies so that is why the BandPassed sounds almost like it damped. The following table has the commands used to BandPass only the lower frequencies and the plots generated from it.

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('catscreech.wav');  >> BandPass(x,sr,1700,1000,1800,1,1800) |

|  |
| --- |
| Output |
| Figure 31.1  Figure 32.1 |

When the same soundwave from before is BandPassed at different frequencies the results can be seen in figure 31. Figure 32 shows how the BandPass technique is trying to smooth out the original soundwave. This soundwave of a mad cat, or as the wav file is titled, “catscreech.wav” is unique because it primarily consists of lower frequencies but then a spike in the higher frequencies happens at certain points in the sound itself. When this BandPassed soundwave is played back so that the lower frequencies are BandPassed it sounds like the original soundwave but does have distinctions between the two. This BandPassed soundwave at the lower frequencies has the higher frequency terms remaining so a listener can still hear the peaks of the soundwave when it is played back. The difference between the original and the BandPassed version at this frequency spectrum is that the BandPassed soundwave sounds muffled since the lower frequency terms are BandPassed out. This is different from the previous BandPass in that it doesn’t sound like the high frequency terms are missing, which is expected from the frequency spectrum that was picked. The following table has the BandStop technique being used on the same soundwave.

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('catscreech.wav');  >> BandStop(x,sr,1700,1000,1900,1,1900) |

|  |
| --- |
| Output |
| Figure 33.1  Figure 34.1 |

From figure 33 the BandStopping of the mad cat soundwave occurs in the higher frequency range. The original and the BandStopped soundwave do not sound much different from one another when they are both played back. There is a difference between the two with no doubt but there is not a huge difference. Figure 34 shows the BandStopped soundwave where MATLAB is trying to smooth out the curves of the soundwave. Figure 33 offers a better comparison between the original and the BandStopped. When the higher frequencies are BandStopped like they are here most of the soundwave stays intact and it primarily for the most part sounds the same when it is played back. This is different from the BandPassing because when the same soundwave was BandPassed in the frequency spectrum that it was, the soundwave that was BandPassed sounded different from the original. It really didn’t matter if it was high or low frequencies that were being BandPassed it sounded different enough to know it was not the original. Similar enough to still know what it was originally. The following table shows the results and commands from when the same soundwave is BandPassed but at different frequencies.

|  |
| --- |
| Input Commands |
| >> [x,sr]=audioread('catscreech.wav');  >> BandStop(x,sr,1700,1,1000,1,1900) |

|  |
| --- |
| Output |
| Figure 35.1  Figure 36.1 |

From figure 35 the cat screech soundwave is BandStopped again but where the lower frequencies are BandStopped. The soundwave when it is played back sounds almost identical to the original soundwave. This is more than likely because the soundwave has the most noticeable parts in it residing in the higher frequency part of the frequency spectrum. Figure 36 shows the BandStopped attempt at smoothing out the function. From this BandStop it should be noted that this soundwave has parts in it that need to be included for it to sound like the original. If the higher frequency terms remain, the BandStop of that soundwave will sound very similar to the original. The following table has all the BandStopping and BandPassing done on the mad cat soundwave.

|  |  |
| --- | --- |
| Figure 29.2 | Figure 30.2 |
| Figure 31.2 | Figure 32.2 |
| Figure 33.2 | Figure 34.2 |
| Figure 35.2 | Figure 36.2 |

**Analysis of Techniques**

For this final project, much can be taken away from the techniques used and the results that they yielded. From Part One, it should be noted that these three soundwaves the cat purring, cat meowing, and mad cat all look different from one another when they are plotted. The one thing that the cat meowing and mad cat soundwaves have in common are that they both consist of higher frequencies in the soundwave itself. When the cat meowing soundwave has one of its dominant frequencies taken out it retains most of its original sound. When the mad cat soundwave has its higher frequencies taken out it also retains most of its sound. The only time a soundwave sounds much different from the original is in the case of the cat purring soundwave. Since most of the soundwave from a cat purring should be thought of as a periodic extension of the previous bit, if one frequency spectrum is taken out it will affect the entire soundwave and alter what it sounds like. No matter what it should be noted that each sound a cat makes is different in some way and not one single conclusion can be made about what a cat sounds like analytically.

One theory that could be proposed from these results are that cats mainly use higher frequency sounds to communicate rather than lower frequency sounds. With humans, we can communicate amongst ourselves no matter the pitch that we use, although it may be beneficial in some cases to use certain pitches. But with cats, when they are happy they typically purr and from the analysis of this project it can be concluded that a cat purring consists of lower frequencies compared to the other sounds that cats make. When cats are neutral or happy, they tend to be making sounds that are at lower frequencies. When cats try to communicate with us, they have sounds come out at higher frequencies. This is evident from the results in this analysis. Cats that tend to be mad also have ranges in frequencies where the highest ones tend to add to the distinction between other sounds. Cats meowing on the other hand have parts of it that are repeated but just at different frequencies, if one of these dominant frequency spreads are taken out, the sound will still resemble the original very well. In short, when cats are happy they tend to make sounds consisting of lower frequencies, when cats are upset or attempting to communicate, they generate sounds at higher frequencies.

# Works Cited

Gay, James. *Wavlist*. 2007. 31 October 2017. <http://www.wavlist.com/soundfx/002/>.

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